Research Report

DETERMINATION OF FIRE HAZARD IN A FIVE PSIA

OXYGEN ATMOSPHERE

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SUMMARY PAGE

THE PROBLEM

A physiologically tolerable oxygen mixture/pressure was investigated for the possible external fire hazard existing therein.

FINDINGS

As compared to the control experiment at sea level pressure in air, it was found that paper ignited at a lower temperature and burned approximately six times as fast in the 5 psia oxygen atmosphere. Neoprene coated nylon twill, light weight nylon, and vinyl plastic all ignited whereas in the control condition they had not ignited but melted. The sacrificed rat was merely singed on its exposed side in the control condition, but the two rats exposed in the 5 psia oxygen atmosphere were burned over their entire body. Toweling material used to test its smothering properties burst completely into flame within one-half second of contact with the fire whereas in the control condition it extinguished the burning paper in one-fourth second.

ACKNOWLEDGMENT

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INTRODUCTION

Many types of artificial atmospheres have been studied (1-10) in an effort to determine the optimum one for use in a space cabin or high altitude gondola. Mixtures of oxygen and nitrogen or some other inert gas, pure oxygen at some specific altitude pressure, or even terrestrial atmosphere at sea level pressure or less must be considered. After the breathing mixtures which will sustain life adequately have been selected, it is essential that each be evaluated in terms of the possibility of hazardous external fire.

Previous experimentation in this respect has not been extensive. In studies (7,8) of human subjects exposed to a simulated altitude of 34,000 feet (3.6 pounds per square inch) with a 100 per cent oxygen atmosphere, an increase in rate of burning of paper at this partial pressure was noted. No ill effects of exposures for up to five days were observed in the subjects.

Shternfeld (10) stated that, if under conditions of weightlessness, a match is struck against the box, the head of the match will burst into flame, but the match will not ignite; no candle or gas will burn. He did not mention ambient gas mixtures. In his book, Soviet Space Science (11), the author wrote, "It should be noted that with a high amount of oxygen (in the cabin) the danger of fire increases, and food products rapidly oxidize and spoil; for this reason the microatmosphere must also contain a certain amount of other gases."

The Project Mercury capsule was designed to maintain an internal atmosphere pressure of 100 per cent oxygen at 5 pounds per square inch absolute (5 psia O_2). This same atmosphere pressure was that of the Mercury full pressure suit (12), and plans (13, 14) for Apollo and Gemini include such a cabin atmosphere.

For this reason it appeared worthwhile to investigate this particular atmosphere for external oxidation hazards and future studies will examine some of the other gas mixtures which seem to sustain life adequately.

PROCEDURE

MATERIAL

A test burn board (Figure 1) was made of asbestos with pedestals of block aluminum. Twenty burn units were installed for placing test strips consisting of: 1) standard burn paper (Whatman No. 40 ash-free filter paper); 2) neoprene coated light weight nylon twill fabric such as used for the inner lining of the Navy, Mark IV full pressure suit; 3) nylon twill 3.25 ounces in weight as used for the outer layer of the Navy, Mark IV full pressure suit; 4) vinyl plastic 0.012 inch thick; and 5) sheet aluminum (0.005 inch, 5052 H2Q QA318). All of these test strips were 0.5 inch in width and 4.5 inches long.

High temperature was provided to the end of each test strip by a coiled, nichrome wire heating element which was energized remotely by an 8 volt DC, 3 amp energy source. While exact temperatures could not be determined, each nichrome element was measured by pyrometer at 1800° F (± 10° F) after five seconds of heating. Theoretical calculations were used to determine temperatures at one, two, three, and four seconds. The test material was in contact with the heating element for each determination.

An additional three-unit section with similar heating elements was used for positioning the bodies of three half-grown Albino rats (mean weight, 220 grams).

A remote-controlled fire smothering device was made of cloth bath toweling and was positioned so that it could be dropped onto a standard burning paper strip at any designated time (Figure 1).

All the materials plus a Beckman p O_2 indicator were installed in a 9A2 low pressure chamber with all the controls mounted outside the chamber.

TESTS

Sea Level in Air

For control measurements, twenty, standard, ash-free filter paper strips were ignited, in sea level pressure in air (Figure 2), and ignition temperature as well as time in which one inch of the paper burned were recorded. Exposed to the heated elements for a maximum of fifteen seconds were: 1) four strips of the neoprene coated light weight nylon twill fabric, 2) six test strips of 3.25 ounce nylon, 3) six test strips of vinylplastic, and 4) four strips of aluminum plate.

A 2-inch piece of standard burn paper ignited by the heating element was placed on the shaved portion of the body of an Albino rat which had been sacrificed with pentobarbital.

Toweling was dropped on top of an ignited paper burn strip (Figure 2) as soon as the paper was aflame to determine the smothering properties of the toweling.

Five Pounds Per Square Inch Oxygen Pressure

The low pressure chamber was evacuated to between 40,000 and 60,000 feet of simulated altitude (2.7 to 1.04 psia) and flooded with oxygen until the simulated altitude was reduced to 26,000 feet (5.2 psia) and the oxygen tension was stabilized in the inside atmosphere between 4.8 and 4.9 psia. Temperature inside the chamber varied between 68° and 72° F, and humidities between 10 to 20 mm Hg.

Twenty paper test strips were ignited (Figure 3) after being in the 4.8 to 4.9 psia oxygen atmosphere for periods varying between five minutes and seven hours. Exposed to the 1800° F heating elements after being in the oxygen atmosphere for various time periods were: 1) five strips of the neoprene coated nylon twill fabric, 2) eight of the 3.25 ounce nylon twill fabric, 3) eight vinyl plastic strips, and 4) four aluminum strips.

The body of one shaved rat which had been sacrificed remained in the oxygen atmosphere for five minutes at which time a test paper placed in contact with its body was ignited. Another rat remained alive for six hours in the same oxygen atmosphere before being sacrificed and exposed to the fire in a similar manner.

After one hour in the oxygen atmosphere a test paper strip was ignited by the heating element (Figure 3). As soon as flame was observed, the towel smothering device was dropped onto the fire.

RESULTS

The findings relative to the test strips of different material under the two experimental conditions are detailed in Tables I and II. These are summarized in Table III along with the observations concerning the Albino rats and the toweling device.

In the sea level pressure in air test it was noted that the Albino rat was singed in the area of its body directly under the burning paper (Figure 4). Fire did not spread to other parts of the body. The dead rat remaining in the oxygen atmosphere for five minutes before being exposed to flame (Figure 5) appeared to burn less severely than the one which remained alive for six hours under the same conditions (Figure 6). Figure 4 also depicts all three rats after exposure to the burning test paper strips.

When the toweling was dropped on the paper test strip under sea level pressure in air, the fire was smothered in 0.25 second (Figure 7). In the oxygen atmosphere, however, the toweling burst into complete flame within one-half second from the heat of the fire (Figure 8) and thus did not make contact with the fire itself; furthermore, it burned completely and partially melted the copper positioning wires. Under these conditions no smothering action of the toweling was possible.

DISCUSSION

To determine if the duration of exposure to 5 psia oxygen had any bearing on our results, an additional test was made in which 21 strips of filter paper were exposed to the 5 psia oxygen atmosphere. It appeared that they ignited at a lower ignition point and burned faster when exposure time was increased from five to thirty-one minutes. This change, however, was not proven by statistical analysis. It might have been caused by a difference in composition of the nichrome heating elements, but after a calibration of each element, only subjective evidence was seen. Furthermore, negative results were obtained statistically when time of exposure was increased from one to seven hours.

Increased time of exposure of mammals to oxygen atmosphere seemed to increase the rate and extent of burning. There is a possibility that, in the rat living for six hours in such atmosphere, body fluids and tissues were being saturated with oxygen.

A possible explanation for the poor smothering properties of material in a 5 psia oxygen atmosphere leads to an academic discussion. It is possible that, when a fire is smothered in air, the inert nitrogen in the air has a dual role; i.e., it carries away part of the heat, and as soon as the 20 per cent atmospheric oxygen has combined with the burning material the remaining 80 per cent atmospheric nitrogen (and the carbon dioxide present as a combustion product) would tend to exclude the entry of additional oxygen to support the combustion. Smothering of fire in an oxygen atmosphere would be complicated because additional oxygen would be available absorbed/adsorbed in the smothering material, and any gas pulled through the smothering material would be oxygen.

CONCLUSIONS

1. An artificial atmosphere of 100 per cent oxygen at an absolute pressure of 5 pounds per square inch presents a significant increase in fire hazard as compared with an atmosphere of air at sea level pressure. This significant increase can be observed in the lowered ignition point and in the increased rate and temperature of burning.

2. It is infinitely more difficult to smother fire in such an atmosphere than one in a sea level pressure atmosphere.

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Table I

Burning or Melting of Various Materials at Sea Level Pressure in Air

Material	Ignition Temp. Minimum	Ignition Temp. Maximum	Flame Temp. Mean	Rate* of Burning/Melting Minimum	Rate* of Burning/Melting Maximum
Paper	1800°F	1800°F plus	1820°F	15.0 sec.	10.5 sec.
Nylon twill-- neoprene coated		melted--did not ignite		7.0 sec.	6.0 sec.
Nylon twill-- 3.25 ounce		melted--did not ignite		15.0 sec.	4.0 sec.
Vinyl plastic		melted--did not ignite		13.0 sec.	10.0 sec.
Aluminum		no effect after 15 seconds			

*Rate is that time required for one inch of the paper strip to burn or for the other materials to melt.

Table II

Burning of Various Materials at Five Pounds Per Square Inch Oxygen Pressure

Material	Ignition Temp. Minimum	Ignition Temp. Maximum	Flame Temp. Mean	Rate* of Burning Minimum	Rate* of Burning Maximum
Paper	1460°F	1759°F	1930°F	3.75 sec.	1.50 sec.
Nylon twill-- neoprene coated	1650°F	1775°F		3.50 sec.	2.50 sec.
Nylon twill-- 3.25 ounce#	1800°F	1800°F plus		7.00 sec.	4.25 sec.
Vinyl plastic	1482°F	1760°F		4.50 sec.	1.75 sec.
Aluminum		no effect after 15 seconds			

*Rate is that time required for one inch to burn.
#Two of these strips melted and did not ignite.

Table III

Summary of Results Obtained after Exposure of Various Materials to Hot Wire at Sea Level Pressure and in Oxygen at Five Pounds Per Square Inch Absolute Pressure

Material	Sea Level Pressure Mean Ignition Temp.	Sea Level Pressure Mean Rate*	5 Psia Oxygen Pressure Mean Ignition Temp.	5 Psia Oxygen Pressure Mean Rate
Paper	1800°F	12.35 sec.	1640°F	2.67 sec.
Nylon twill-- neoprene coated	Did not ignite	Melted	1680°F	3.00 sec.
Nylon twill-- 3.25 ounce	Did not ignite	Melted	1800°F plus	5.40 sec.
Vinyl plastic	Did not ignite	Melted	1700°F	3.70 sec.
Aluminum	Did not ignite	No effect	Did not ignite	No effect
Rat	1800°F	Singed	1800°F	Fire covered entire body
Toweling	Paper burning at 1800°F	Fire smothered	Paper ignited at 1640°F	Toweling burned completely

*Rate is the mean time required for one inch of material to burn or for melting.

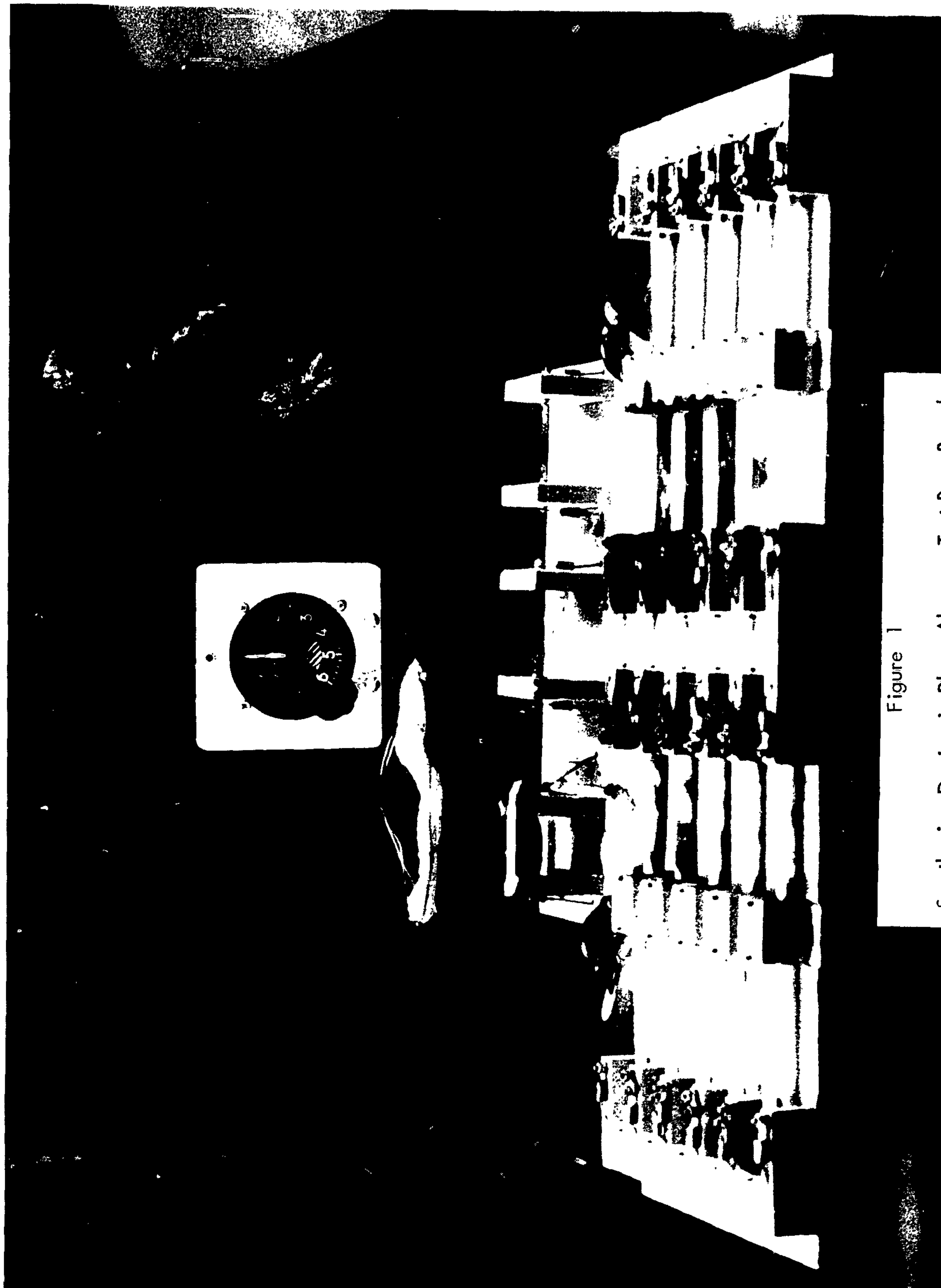

Figure 1

Smothering Device in Place Above a Test Burn Board

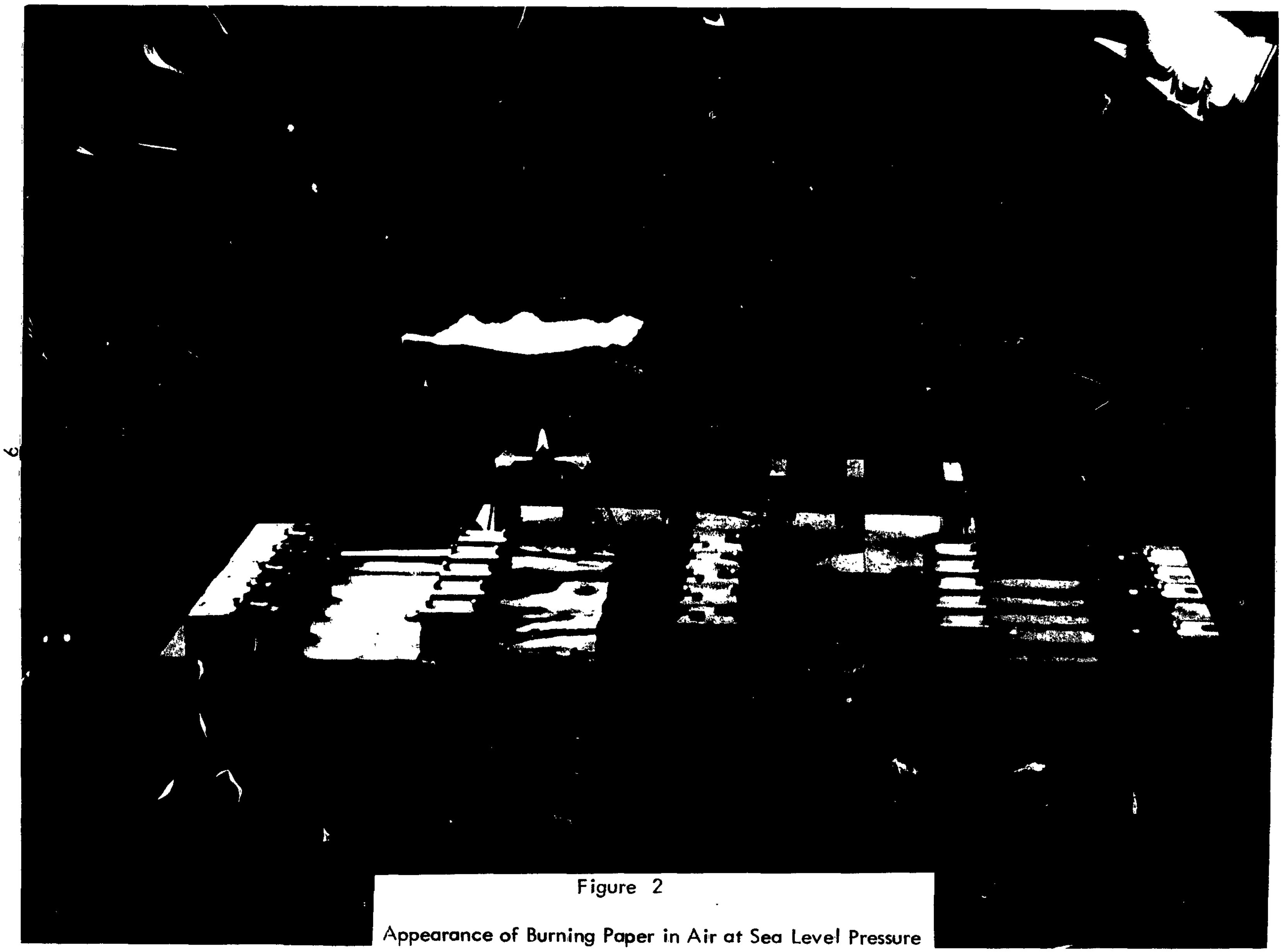

Figure 2

Appearance of Burning Paper in Air at Sea Level Pressure

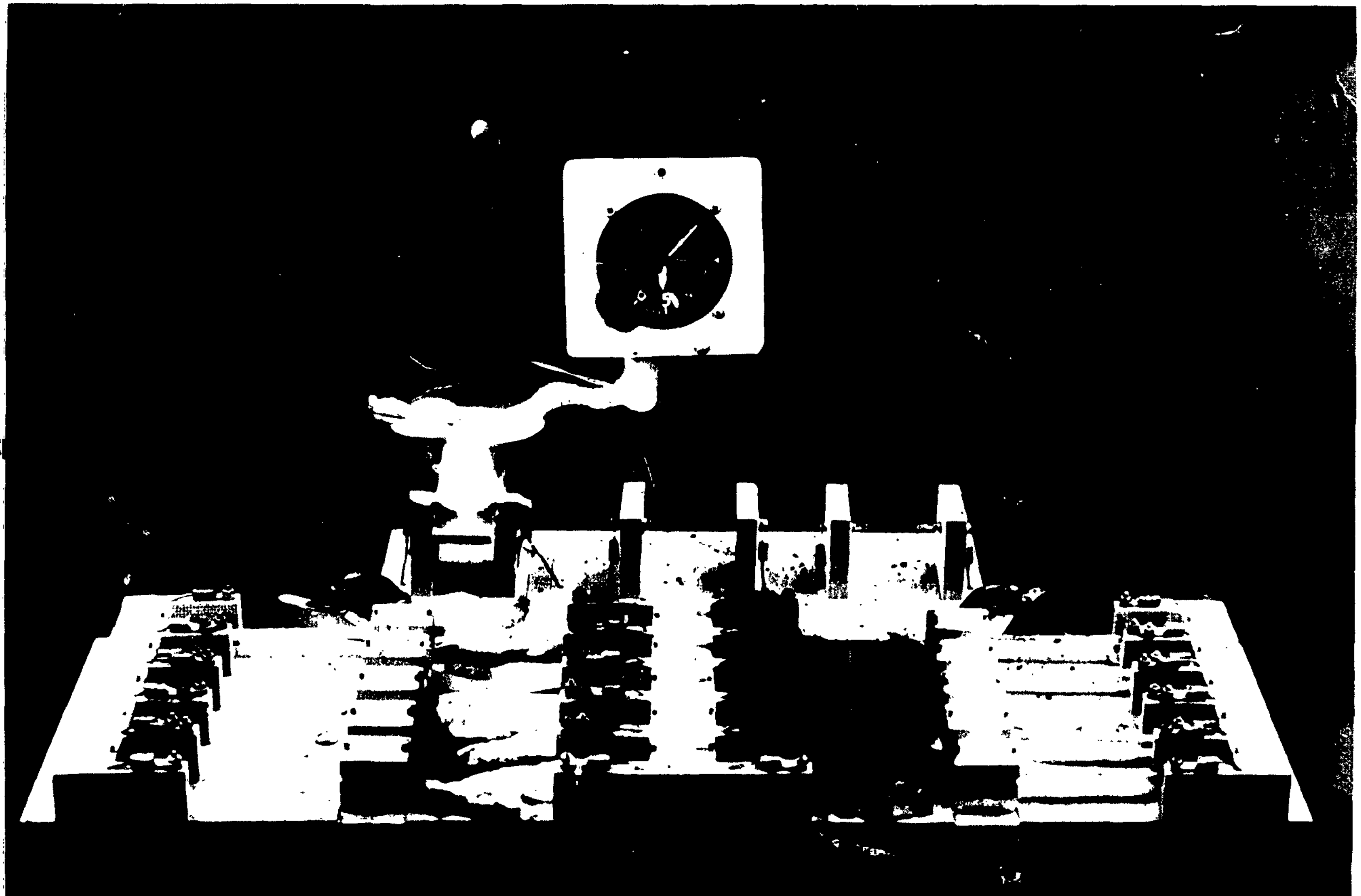

Figure 3

Appearance of Burning Paper at Five Psia Oxygen Pressure

Figure 4

Albino Rats Exposed to Burning Paper

Right: Rat in air at sea level pressure. Middle: Sacrificed rat after five minutes in 5 psia oxygen atmosphere. **Left:** Rat living in 5 psia oxygen atmosphere for six hours.

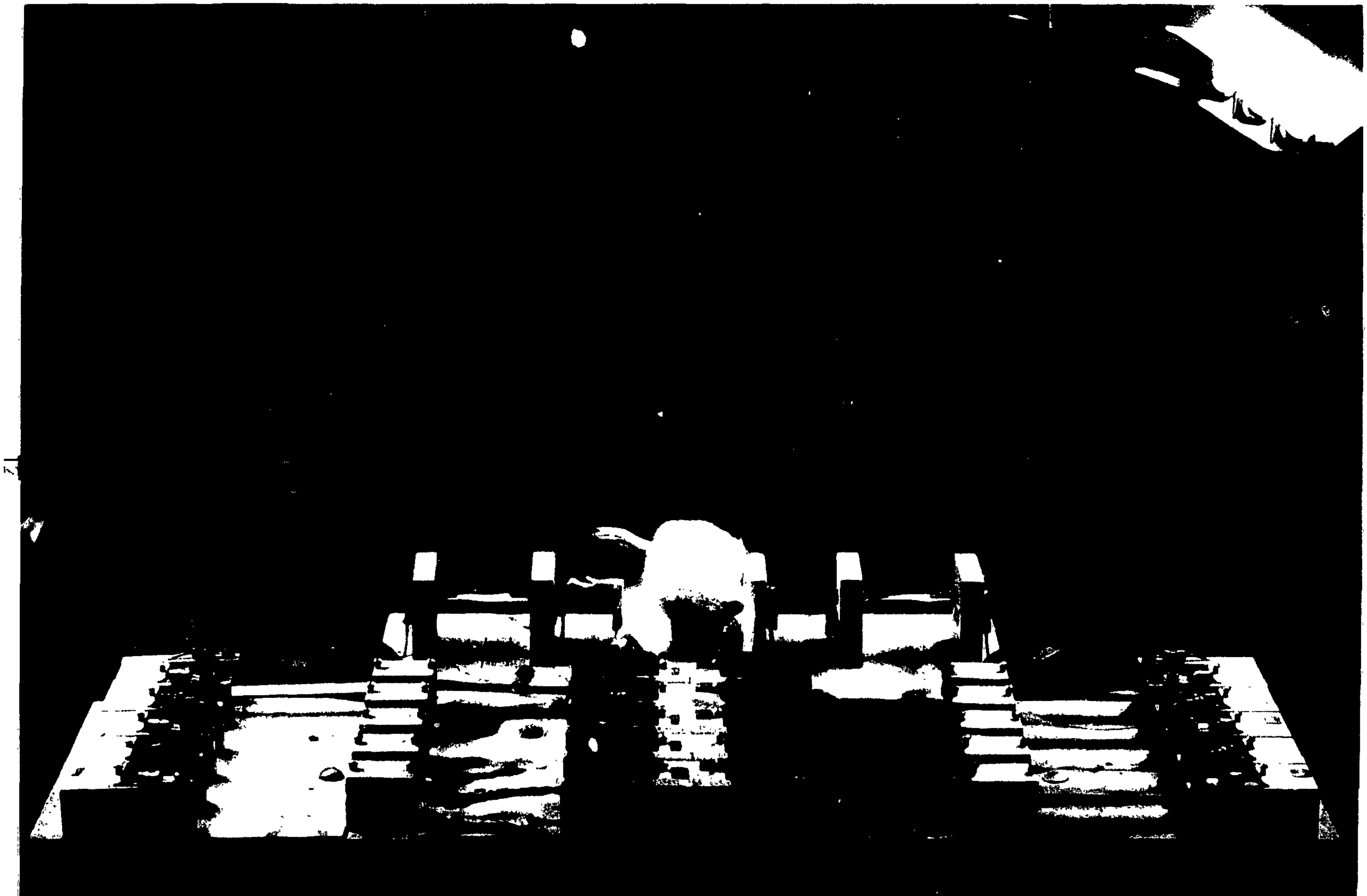

Figure 5

Sacrificed Albino Rat Afire after Five Minutes in Five Psia Oxygen Atmosphere

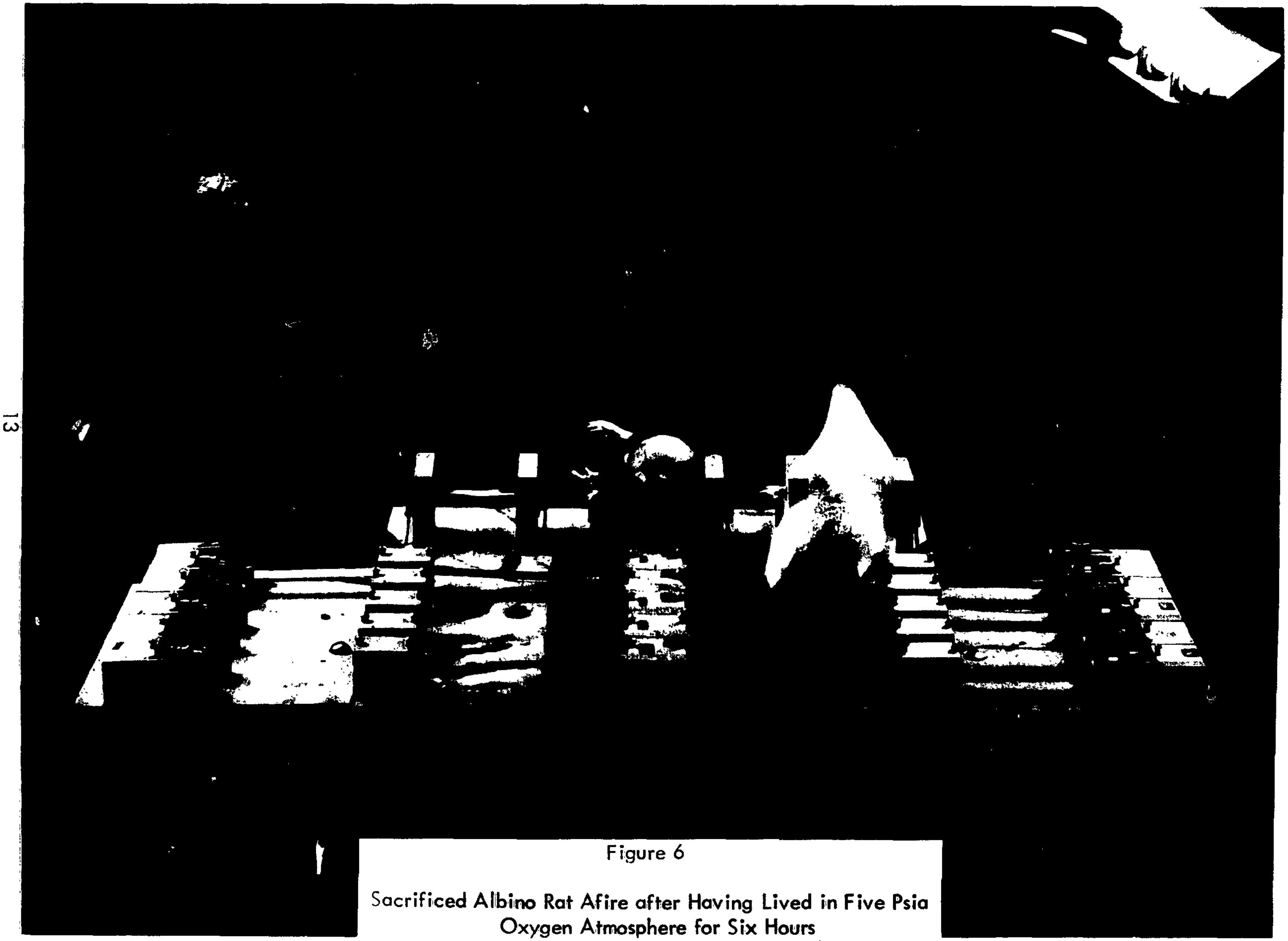

Figure 6

Sacrificed Albino Rat Afire after Having Lived in Five Psia Oxygen Atmosphere for Six Hours

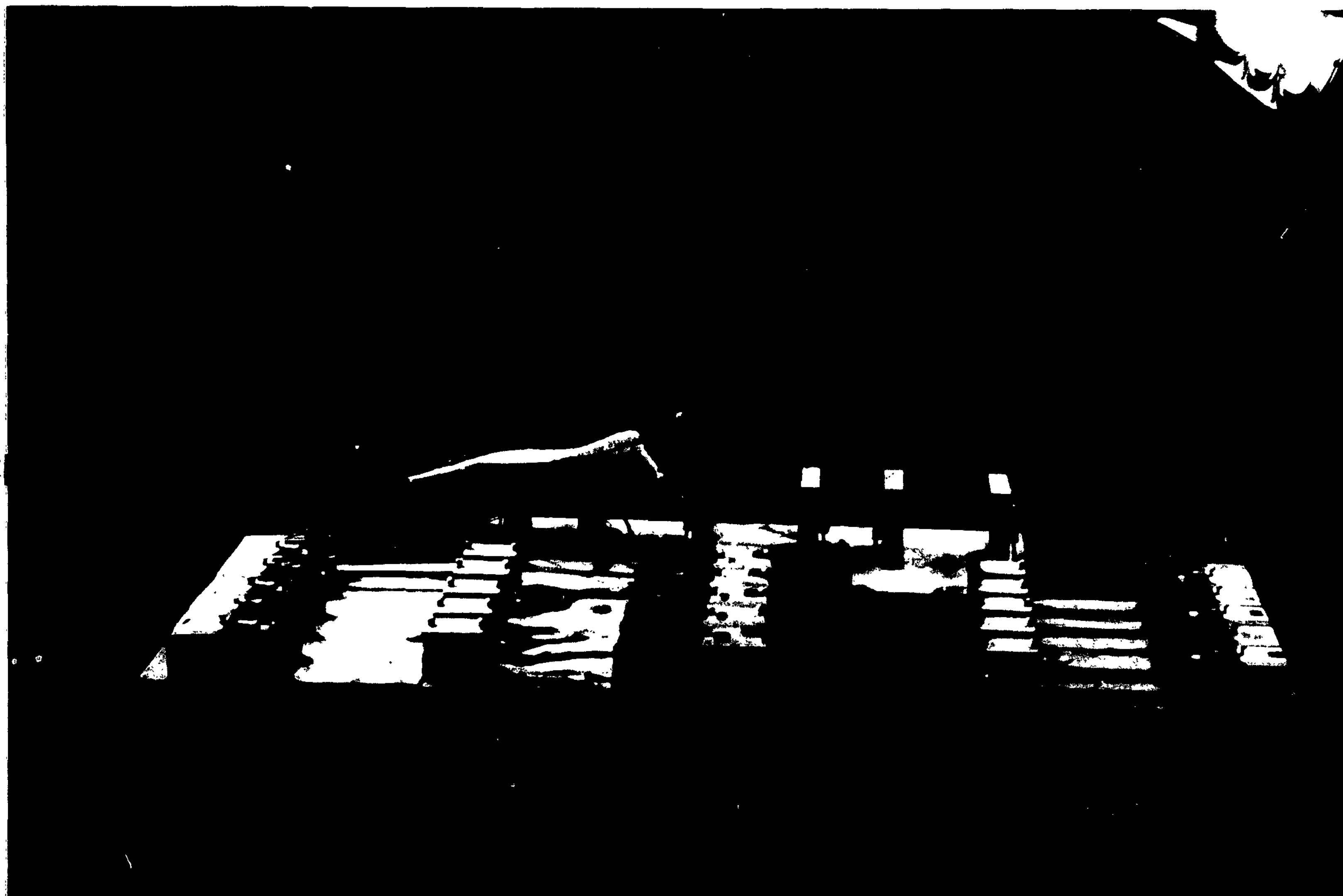

Figure 7

Paper Fire Smothered in Air at Sea Level Pressure

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Aviation physiology

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Figure 8

Toweling Smother Device Dropped over Burning Paper in Five Psia Oxygen Atmosphere (Time elapsed from Fig. 3 was one-half second)